본 수업의 주 교재는 Silberschatz, Galvin, Gagne, "Operating System Concepts Essentials 2nd ed.", Wiley, 또는 한글번역본인 박민규, 조유근, "Operating System Concepts 에센셜 2판", 홍릉과학출판사입니다. 본 강의 동영상의 슬라이드는 이 책의 홈페이지에서 제공하는 것을 사용했음을 밝힙니다(https://codex.cs.yale.edu/avi/os-book/OSE2/slide-dir/index.html). 다만 강의의 편의를 위해 내용 변경 없이 슬라이드 레이아웃을 변경하였고, 진도 관리에 필요한 경우 일부 슬라이드는 생략하였습니다.

Chapter 9: Mass-Storage Structure

Structure of secondary storage devices

Performance characteristics of mass-storage devices

Disk scheduling algorithms

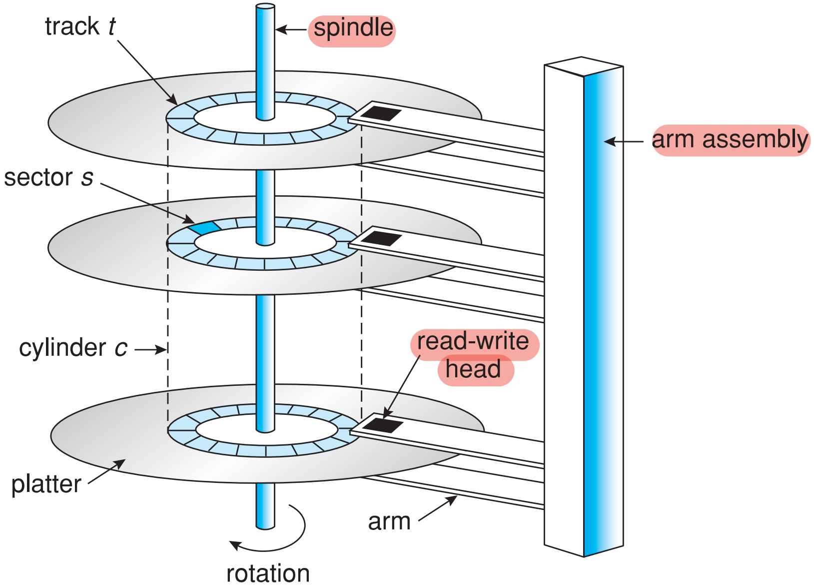
Contents

- Overview of Mass Storage Structure
- Disk Structure
- Disk Attachment
- Disk Scheduling
- Disk Management
- Swap-Space Management
- RAID Structure
- Stable-Storage Implementation

9.1 Overview of Mass Storage Structure

- Magnetic disks provide bulk of secondary storage of modern com puters =HDD
  - Drives rotate at 60 to 250 times per second ⇒ rpm으로 환산하기.
  - Transfer rate is rate at which data flow between drive and computer
  - Positioning time (random-access time) is time to move disk arm to desired cylinder (seek time) and time for desired sector to rotate under the disk he ad (rotational latency)
  - Head crash results from disk head making contact with the disk surface
- Disks can be removable
- Drive attached to computer via I/O bus
  - Busses vary, including EIDE, ATA, SATA, USB, Fibre Channel, SCSI, SAS, Firewire
  - Host controller in computer uses bus to talk to disk controller built into dri ve or storage array

Moving-head Disk Mechanism



Hard Disks

- Platters range from .85” to 14” (historically)
    - Commonly 3.5”, 2.5”, and 1.8”
- Range from 30GB to 3TB per drive
- Performance
    - Transfer Rate – theoretical – 6 Gb/sec
    - Effective Transfer Rate – real – 1Gb/sec
    - Seek time from 3ms to 12ms – 9ms common for desktop drives
    - Average seek time measured or calculated based on 1/3 of tracks
    - Latency based on spindle speed
        - 1 / (RPM / 60) = 60 / RPM
    - Average latency = ½ latency

Hard Disk Performance

- Access Latency = Average access time = average seek time + average latency
  - For fastest disk 3ms + 2ms = 5ms
  - For slow disk 9ms + 5.56ms = 14.56ms
- Average I/O time = average access time + (amount to transfer / transfer rate) + controller overhead
- For example to transfer a 4KB block on a 7200 RPM disk with a 5 ms average seek time, 1Gb/sec transfer rate with a .1ms controller overhead =
  - 5ms + 4.17ms + 0.1ms + transfer time =
  - Transfer time = 4KB / 1Gb/s * 8Gb / GB * 1GB / 1024^2KB = 32 / (1024^2) = 0.031 ms

    Bit , Byte의차이를 제거하기위해 통일.
  - Average I/O time for 4KB block = 9.27ms + .031ms = 9.301ms

Disk Structure

- Disk drives are addressed as large 1-dimensional arrays of **logical blocks**, where the logical block is the smallest unit of transfer
  - Low-level formatting creates **logical blocks** on physical media
- The 1-dimensional array of logical blocks is mapped into the sectors of the disk sequentially
  - Sector 0 is the first sector of the first track on the outermost cylinder
  - Mapping proceeds in order through that track, then the rest of the tracks in that cylinder, and then through the rest of the cylinders from outermost to innermost
  - Logical to physical address should be easy
    - Except for bad sectors
    - Non-constant # of sectors per track via constant angular velocity

Solid-State Disks

≈ SSD

- Nonvolatile memory used like a hard drive
    - Many technology variations
- More expensive per MB
- Maybe have shorter life span
- Less capacity
- But much faster
- Can be more reliable than HDDs
- Busses can be too slow -> connect directly to PCI for example
- No moving parts, so no seek time or rotational latency

Magnetic Tape

- Was early secondary-storage medium
  - Evolved from open spools to cartridges
- Relatively permanent and holds large quantities of data
- Access time slow
- Random access ~1000 times slower than disk
- Mainly used for backup, storage of infrequently-used data, transfer medium between systems
- Kept in spool and wound or rewound past read-write head
- Once data under head, transfer rates comparable to disk
  - 140MB/sec and greater
- 200GB to 1.5TB typical storage

Disk Scheduling

- The operating system is responsible for using hardware efficiently — for the disk drives, this means having a fast access time and disk bandwidth
- Minimize seek time
- Seek time ≈ seek distance
- Disk bandwidth is the total number of bytes transferred, divided by the total time between the first request for service and the completion of the last transfer

Disk Scheduling (Cont.)

- There are many sources of disk I/O request
  - OS
  - System processes
  - Users processes

입출력 시작 주소.

- I/O request includes input or output mode, disk address, memory address, number of sectors to transfer
- OS maintains queue of requests, per disk or device
- Idle disk can immediately work on I/O request, busy disk means work must queue
  - Optimization algorithms only make sense when a queue exists

Disk Scheduling (Cont.)

- Several algorithms exist to schedule the servicing of disk I/O requests
- The analysis is true for one or many platters
- We illustrate scheduling algorithms with a request queue (0-199)

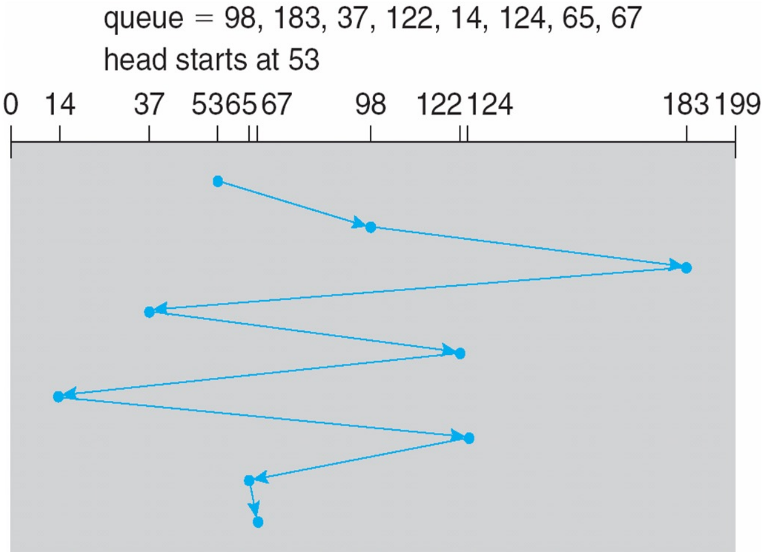
98, 183, 37, 122, 14, 124, 65, 67

Head pointer 53

FCFS

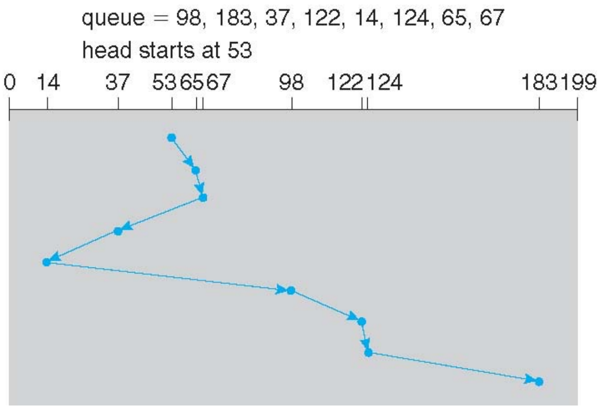
먼저온놈 먼저 서비스

Illustration shows total head movement of 640 cylinders



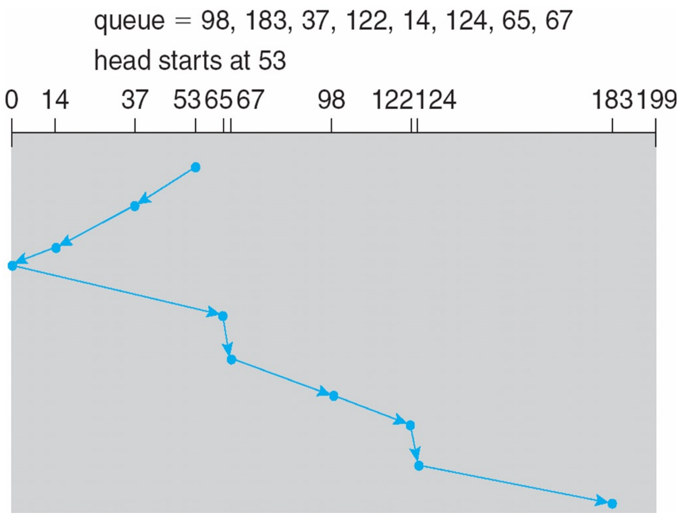
SSTF

- Shortest Seek Time First selects the request with the minimum seek time from the current head position
- Illustration shows total head movement of 236 cylinders
- SSTF scheduling is a form of SJF scheduling; may cause starvation of some requests



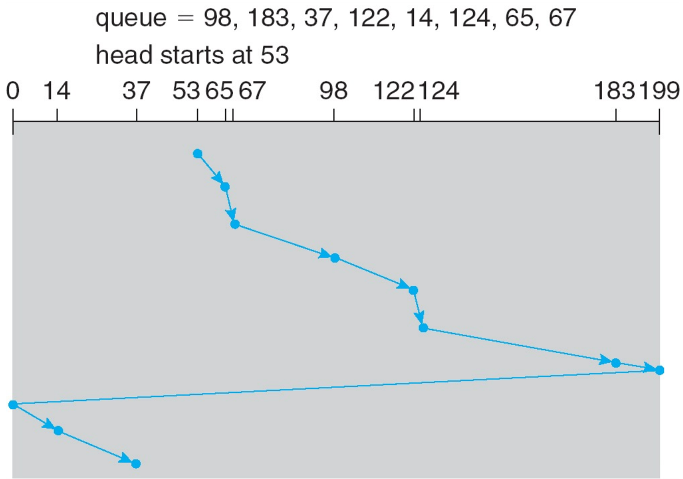
SCAN

- The disk arm starts at one end of the disk, and moves toward the o ther end, servicing requests until i t gets to the other end of the dis k, where the head movement is r eversed and servicing continues.
- Illustration shows total head mov ement of 236 cylinders
- SCAN algorithm sometimes called the elevator algorithm
- But note that if requests are unifo rmly dense, largest density at oth er end of disk and those wait the longest



C-SCAN

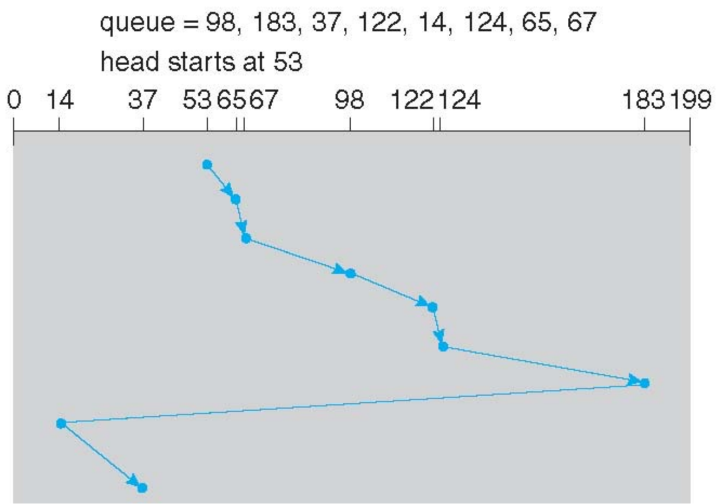
- Provides a more uniform wait time than SCAN
- The head moves from one end of the disk to the other, servicing requests as it goes
  - When it reaches the other end, however, it immediately returns to the beginning of the disk, without servicing any requests on the return trip
- Treats the cylinders as a circular list that wraps around from the last cylinder to the first one
- Total number of cylinders?



C-LOOK

- LOOK a version of SCAN, C-LOOK a version of C-SCAN
- Arm only goes as far as the last request in each direction, then reverses direction immediately, without first going all the way to the end of the disk
- Total number of cylinders?

322



Selecting a Disk-Scheduling Algorithm

- SSTF is common and has a natural appeal
- SCAN and C-SCAN perform better for systems that place a heavy load on the disk
  - Less starvation
- Performance depends on the number and types of requests
- Requests for disk service can be influenced by the file-allocation method
  - And metadata layout
- The disk-scheduling algorithm should be written as a separate module of the operatin g system, allowing it to be replaced with a different algorithm if necessary
- Either SSTF or LOOK is a reasonable choice for the default algorithm
- What about rotational latency?
  - Difficult for OS to calculate
- How does disk-based queueing effect OS queue ordering efforts?

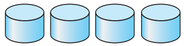
9.7 RAID Structure

- RAID – redundant array of inexpensive (independent) disks
  - Improvement of reliability via redundancy
  - Improvement in performance via parallelism
- Mirroring - improves the reliability of the storage system by storing red undant data
- Mean time to failure of a mirrored disk can be affected by two factors: single disk's mean time to failure and mean time to repair
  - If mirrored disks fail independently, consider disk with 100,000hr mean time to fail ure and 10 hour mean time to repair
  - Mean time to data loss is $100,000^2 / (2 * 10) = 500 * 106$ hours, or 57,000 years!
- Data striping
  - Bit-level striping
  - Block-level striping

RAID (Cont.)

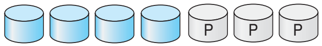
- RAID is arranged into six different levels
- RAID schemes improve performance and improve the reliability of the storage system by storing redundant data
  - Mirroring or shadowing (RAID 1) keeps duplicate of each disk
  - Block interleaved parity (RAID 4, 5, 6) uses much less redundancy
  - Striped mirrors (RAID 1+0) or mirrored stripes (RAID 0+1) provides high performance and high reliability
- Frequently, a small number of hot-spare disks are left unallocated, automatically replacing a failed disk and having data rebuilt onto them

RAID Levels

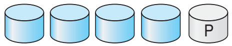


(a) RAID 0: non-redundant striping.

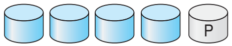
(b) RAID 1: mirrored disks.



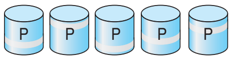
(c) RAID 2: memory-style error-correcting codes.



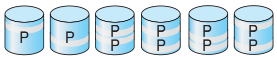
(d) RAID 3: bit-interleaved parity.



(e) RAID 4: block-interleaved parity.

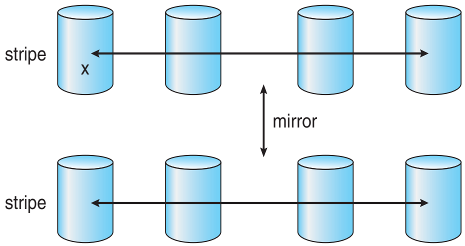


(f) RAID 5: block-interleaved distributed parity.

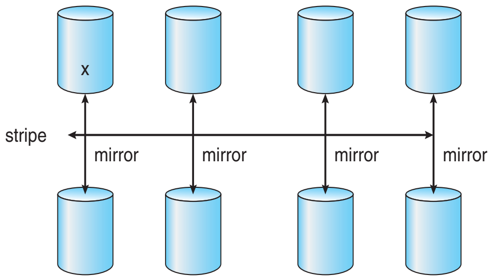


(g) RAID 6: P + Q redundancy.

RAID (0 + 1) and (1 + 0)



a) RAID 0 + 1 with a single disk failure.



b) RAID 1 + 0 with a single disk failure.